Texture-based Instrument Segmentation in 3D Ultrasound Images

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PURPOSE:
To improve the distorted appearance of instruments in new real-time 3D ultrasound for instrument and tissue tracking in intracardiac beating heart procedures. While echographic images are fast and cheap for use in the operating room, they are also noisy and hard to interpret. Tissue and instruments have similar gray levels in US images, which makes their correct delineation difficult. Furthermore, the interface between instruments and tissue is fuzzy and confusing to the surgeon.

METHOD:
Our work estimates from expert-segmented images the statistical distributions of blood, tissue and instrument in intracardiac procedures. First, we build averaged probability distribution functions for the three mentioned classes. The voxel intensity used to determine its class uses information from the neighboring voxels through a smoothing kernel of determined size and standard deviation. The labeling of voxels is done through an iterative expectation-maximization algorithm. Once the three groups of voxels are separated, more neighboring information is used to give spatial information based on the shape of instruments in order to correct for voxels falsely labeled as tissue inside the instrument and vice-versa. We analyze the major axis of segmented data through their principal components and refine the results by a watershed transform by immersion, which corrects the results at the contact between instrument and tissue.

RESULTS:
We used both 3D in-vitro data, from a tank trial with an acetal rod approaching a tissue sample, and in-vivo data, from a surgical operation performed with a wooden instrument in a porcine beating heart. The training sets and test data are acquired under similar imaging conditions and using the same instrument material. All data was acquired with a Philips Live 3D Echo Scanner. The results on expert-annotated images show the correct segmentation and position of the instrument shaft oriented towards the ultrasound probe in both situations. The instrument orientation is extracted from its principal components.

NOVELTY:
Tissue texture analysis has been used previously to segment cardiac images. Very little work has been presented toward the segmentation of instruments, mainly concerned with the orientation of instruments in tank settings and without interaction between instruments and tissue. We add instruments to tissue and blood in our analysis of in-vivo data acquired in clinical condition and find both the position and orientation of instruments.

CONCLUSION:
We presented an algorithm for the segmentation of instruments in 3D ultrasound images with very promising results in in-vivo data, where instruments appear confusing in the presence and in contact with tissue. Our segmentation results can be used as an initialization step for tracking instruments and tissue in 4D echocardiography.

DISCLAIMER:
This work has not been submitted for publication or to any other conference or journal.

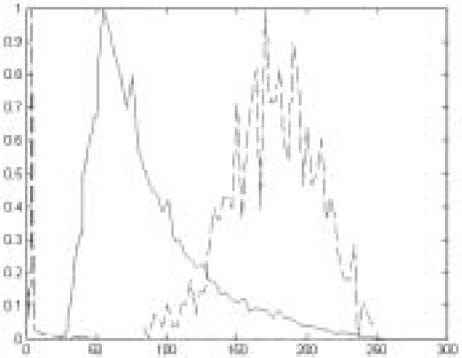

Figure 1: The normalized histograms of blood (dashed-left), in-vivo parenchyma (middle) and wood-instrument (dashed-right).

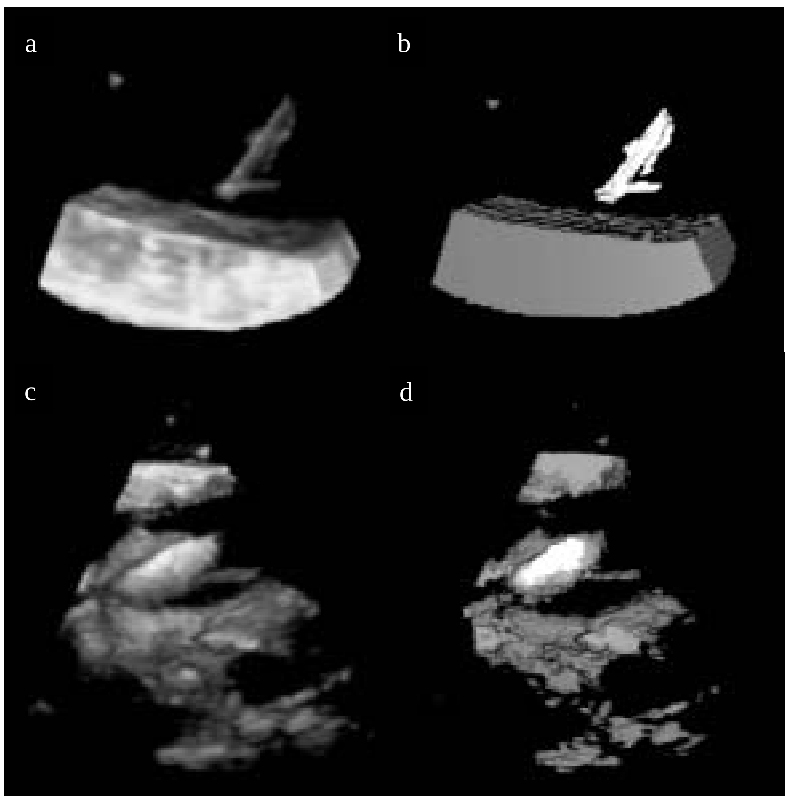

Figure 2. Segmentation results: (a) a 3D US image of an acetal rod approaching a tissue sample in a water tank, which was used for the in-vitro tests; (b) the 3D segmentation results for image (a) with the instrument, reverberation and tip artifact adjacent to the instrument shown in white and tissue in gray; (c) a 3D US image of a porcine beating heart with a wooden rod inside (in contact with the tissue) acquired in clinical conditions, which was used for the in-vivo experiments; (d) 3D segmentation results for image (c).